

D E S C R I P T I O N

TITLE OF THE INVENTION

TURBO COMPRESSOR AND METHOD OF OPERATING THE
TURBO COMPRESSOR

5 **TECHNICAL FIELD**

The present invention relates to a turbo-compressor and an operating method thereof, and in particular, it relates to a turbo-compressor and an operating method, for preventing the compressor from surging, thereby improving the operation of the
10 turbo-compressor.

BACKGROUND ARTS

With the conventional turbo-compressor to be applied into a chemical plant and so on, in many cases, a discharge pressure is set to be almost constant in the specification thereof. In such
15 turbo-compressor, however, the discharge pressure changes if temperature and/or pressure of a suction gas is changed, even when the rotational speed is constant. As a result thereof, there is a possibility that it cannot reach to a predetermined discharge pressure. Then, as is described in Japanese Patent Laying-Open
20 No. Sho 56-121898 (1981), for example, detection is made upon the temperature and the pressure of a working gas sucked into, as early as possible, so as to change the rotational speed of a driving machine responding to the temperature and pressure of a gas sucked into, which are detected, thereby controlling the turbo-compressor
25 so that the discharge pressure thereof comes to be the predetermined one.

Other example of the conventional turbo-compressor is also

described in Japanese Patent Laying-Open No. Hei 1-200095 (1989),
for example. Within a multi-staged centrifugal compressor
described in that publication, the minimum rotation speed of the
driving machine is changed or altered responding to the changes
5 of temperature of the suction gas, so as to prevent it from an
unstable phenomenon, i.e., so-called the surging, thereby
operating the compressor with stability, within a wide operation
range thereof. Also, as is described therein, for example, in
Japanese Patent Laying-Open No. Hei 10-89287 (1998), detection
10 is made upon the temperature of a working gas sucked into a
turbo-compressor, so as to change the rotational speed of the
compressor in relation to about 1/3 power of a ratio between the
detected temperature of the suction gas and a reference temperature
thereof, thereby lowering the power of a shaft under a constant
15 gas pressure control, for controlling the discharge pressure from
the turbo-compressor at a constant.

Separating from those conventional arts, in each of which
the constant gas pressure control is obtained by changing the
rotational speed of the compressor, but in Japanese Patent
20 Laying-Open No. Sho 62-96798 (1987), for example, there is
described that change is made upon an angle of a vane of an inlet
guide vane, which is provided at a suction side of the compressor,
corresponding to the temperature of the gas sucked into the
turbo-compressor, thereby to adjust a flow rate with high accuracy.

25 However, within such the turbo-compressors which are
described in the Japanese Patent Laying-Open No. Sho 56-121898
(1981), the Japanese Patent Laying-Open No. Hei 1-200095 (1989)
and in the Japanese Patent Laying-Open No. Hei 10-89287 (1998)
mentioned above, although the rotational speed of the compressor
30 is controlled depending upon the temperature of the suction gas;
however, in order to change the rotational speed within the
turbo-compressor, which is driven by an electric motor, there is
a necessity of providing an electric motor with an inverter drive,
therefore it comes to be high in the price thereof. Also, with

such the compressor that is described in the Japanese Patent Laying-Open No. Sho 62-96798 (1987), no consideration is paid upon an idea for expanding or widening the stable operation region of the compressor when conducting a capacity control thereupon, but
5 escaping from the surging.

An object of the present invention, accomplished by taking the drawbacks of the conventional technologies mentioned above into the consideration thereof, is to provide a turbo-compressor of being driven by an electric motor, thereby enabling to maintain
10 a wide operation range or region, but without generating the surging therein, while keeping the discharge pressure thereof at about constant. Other object, according to the present invention, is to provide a turbo-compressor of a simple structure, enabling to maintain a wide operation range or region. And, according to the
15 present invention, it is also another object to accomplish any one of those mentioned above.

DISCLOSURE OF THE INVENTION

According to the present invention, for achieving the object mentioned above, first there is provided a turbo-compressor,
20 comprising: an inlet guide vane enabling to change a vane angle thereof; a blow-off valve; a suction condition detecting means for detecting at least one of temperature and suction pressure of a working gas sucked into said turbo-compressor; and a controlling means having a database relating to a minimum angle
25 of said inlet guide vane with respect to the suction condition.

According to the present invention, for achieving the object mentioned above, there is further provided a turbo-compressor, comprising: an inlet guide vane enabling to change a vane angle thereof; a main body of a turbo-compressor; a discharge pressure
30 detecting means for detecting discharge pressure of said turbo-compressor; a check valve being positioned at a side of said turbo-compressor main body than said discharge pressure detecting

means; a blow-off valve for blowing off a gas compressed within said turbo-compressor; a suction condition detecting means being positioned in an upstream side of said inlet guide vane, for detecting at least one of temperature and suction pressure of a working gas sucked into said turbo-compressor; and a regulator for controlling an angle of said inlet guide vane and opening/closing of said blow-off valve, and further comprising, a surging detecting means being provided between said check valve and said turbo-compressor main body, and a database being provided within said regulator, for describing therein a relationship between a suction condition and a minimum inlet guide vane angle with respect to a target pressure, respectively.

And, according to the present invention, in the turbo-compressor as described in the above, it is preferable that said regulating means renews data of the minimum inlet guide vane angle within said database when said surging detecting means detects a surging, and it is also possible that the compressor further comprises a higher controller for controlling said regulating means.

Further, according to the present invention, for achieving the object mentioned above, there is also provided an operation method of a turbo-compressor, for controlling discharge pressure of said turbo-compressor with using an inlet guide vane and a blow-off valve, comprising the following steps of: detecting a value through a temperature detecting means or a pressure detecting means; obtaining a minimum inlet guide vane angle at that detection value by referring to data of the minimum inlet guide vane angle, which are memorized in a regulator equipped with said compressor, upon basis of said detection value; and driving said inlet guide vane at that minimum angle or greater than that through a vane driver.

Also, according to the present invention, in the operation method of a turbo-compressor as described in the above, it is preferable: said data of the inlet guide vane angle is renewed

while opening the inlet guide vane by a predetermined amount when a surging generates within said turbo-compressor; a characteristic of the discharge pressure of the compressor to the suction flow rate is memorized into the regulator, and when the inlet guide vane angle which is obtained from said characteristic upon changing of said suction flow amount comes down to be smaller than the minimum inlet guide vane angle, the inlet guide vane is set at the minimum inlet guide vane angle while opening the blow-off valve; a deviation of a vane angle is obtained when the discharge pressure is higher than a target discharge pressure, and when the vane angle added with the deviation comes down to be equal or less than the minimum inlet guide vane angle, the inlet guide vane is set at the minimum inlet guide vane angle while opening the blow-off valve; and the compressor is shifted into a non-load operation condition by fully opening the inlet guide vane when the discharge pressure is higher than a target discharge pressure and the blow-off valve, and when this condition continues for a predetermined time period, then the compressor is stopped on the operation thereof.

BRIEF DESCRIPTION OF DRAWINGS

Figs. 1 through 3 are views for explaining about the characteristics of the turbo-compressor, wherein:

Fig. 1 is a view for explaining a relationship between suction flow rate and discharge pressure;

Fig. 2 is a view for explaining changes on the characteristic curve due to the difference in temperature of a suction gas; and

Fig. 3 is a view for explaining changes on the characteristic curves due to the difference in the suction pressure; and further,

Fig. 4 is a system view of the turbo-compressor according to one embodiment of the present invention; and

Figs. 5 and 6 show a flowchart for showing an operation control of the turbo-compressor shown in Fig. 4.

BEST MODE FOR CARRYING OUT THE INVENTION

Hereinafter, explanation will be made about a
5 turbo-compressor, according to an embodiment of the present invention, by referring to the drawings attached herewith. Figs. 1 to 3 are views for showing the characteristics of the compressor, in particular, in a case where a constant gas pressure control is applied for controlling the rotational speed of the
10 turbo-compressor at a constant, while providing an inlet guide vane at the suction side of that turbo-compressor. Within such a kind of the conventional turbo-compressor, however the minimum opening " β_{\min} " of the inlet guide vane is set at a constant, so as to avoid the surging therefrom.

15 Fig. 1 shows a " Q_s - P_d " characteristic curve, being a relationship between the flow rate and the discharge pressure within the turbo-compressor, in particular, in the case where the constant gas pressure control is applied so that the discharge pressure " P_d " comes to be a target pressure " P_t ". A dotted line
20 " SL " shows a surging line. When changing an inlet guide vane opening " β " so as to change the suction flow rate " Q_s ", then the suction flow rate changes along with a one-chain dotted line shown within the figure, so that the discharge pressure " P_d " comes to be equal to the target pressure " P_t ". Then, when the inlet guide vane opening
25 " β " comes to be equal or less than the minimum opening " β_{\min} " thereof, the surging is generated within such the constant gas pressure control. On the contrary to this, when operating the compressor while keeping the inlet guide vane opening " β " at the constant, then the discharge pressure " P_d " changes, as is shown by a solid
30 line in the figure, depending upon changes of the suction flow rate " Q_s ". A range or region of flow rate when the control is made upon so as to obtain the target discharge pressure " P_d " while

changing the inlet guide vane opening from the maximum, i.e., " β_{\max} " up to the minimum, i.e., " β_{\min} ", it is a stable operation range or region "Qst".

By the way, within the turbo-compressor, when the temperature is changed of the working gas sucked into the compressor, then the characteristics thereof are also changed. For example, if the temperature " T_s " of the working gas sucked into is the temperature " T_{s1} " of a summer season, i.e., $T_s = T_{s1}$, then the discharge pressure " P_d " shows such a characteristic to the suction flow rate " Q_s ", as is shown by a broken line "B1" in the figure. If the temperature " T_s " of the suction gas falls down to that of a winter time, i.e., $T_s = T_{s2}$, then the discharge pressure " P_d " comes to be such a characteristic as shown by a solid line "A1" in the figure.

In this Fig. 2, a stable operation region "Q T_{s2} " of the compressor is wide when the temperature " T_s " of the sucked working gas is low (such as, $T_s = T_{s2}$), comparing to the stable operation region "Q T_{s1} " when the suction gas temperature " T_s " is high (such as, $T_s = T_{s1}$). Thus, according to the conventional method for avoiding the surging therefrom; i.e., keeping the opening " β " of the variable inlet guide vane at the maximum opening " β_{\max} ", even in the winter season where the temperature " T_s " is low of the suction gas, however it is necessary to set up or determine the opening of the inlet guide vane, upon the basis of a surging critical flow rate of the summer season, being larger than that of the winter season, having a possibility that such the surging may occur. As a result thereof, even in a time when no surging will occur at that guide vane operation because of the low temperature of the suction gas, it is compelled to conduct a wasteful operation; i.e., operating the compressor while blowing off the gas through the flow-off valve opened, as an operation for avoiding the surging.

However, the characteristics of the turbo-compressor also change depending upon the suction pressure of the working gas.

Fig. 3 shows a manner of changing in the relationship between the suction flow rate " Q_s " and the discharge pressure " P_d ". Change of the discharge pressure is shown by a broken line "B2" when the suction flow rate is changed while keeping the angle of the inlet guide vane at a constant, in particular, if the suction pressure is low ($P_s = P_{s1}$), while change of the discharge pressure is shown by a solid line "A2" when change is made in the similar manner, but in particular, if the suction pressure is high ($P_s = P_{s2}$). Also, surge lines are shown by broken lines "SL1" and "SL2", respectively, each of which defines a boundary of generating the surging under each condition thereof. As is shown in Fig. 3, the stable operation region " Q_{Ps1} " under the suction pressure " P_{s1} " is narrower than the stable operation region " Q_{Ps2} " under the suction pressure " P_{s2} ". Namely, the higher the suction pressure " P_s ", the wider the stable operation region. However, the stable operation region of the turbo-compressor also changes depending upon, not only the temperature and the pressure of the suction gas, but also due to dirt within an inside and/or a secular degradation thereof, etc.

Within the turbo-compressor, in which the characteristics change depending upon the suction condition and so on, in this manner, movements for achieving an effective flow rate control up to the surge limit will be explained by referring to Fig. 4. This Fig. 4 is a system view for showing an embodiment of the turbo-compressor driven by an electric motor, according to one embodiment of the present invention. Solid lines depict the actual flow conditions of the working gas, while broken lines depict electric flows of various signals. The turbo-compressor according to the present embodiment has three (3) stages of compressor chambers 3, 5 and 7. Between each pair of the compressor chambers are provided an inter coolers 4 and 6, respectively, and within a downstream of the last stage compressor 7 is provided an after cooler 8. At an inlet side of the first stage compressor 5 is provided a variable inlet guide vane 2, and within an upstream of that variable inlet guide vane 2 is provided a suction filter 1, respectively.

Within the turbo-compressor being constructed in such the manner, after passing through the suction filter 1, the working gas flows into the variable inlet guide vane 2. The temperature "Ts" and the pressure "Ps" of suction gas are always changing depending upon the changes of temperature and pressure in the periphery of the turbo-compressor, and pressure loss of the filter and so on, as well. Then, a temperature sensor 11 is attached or provided within a flow pass between the suction filter 1 and the inlet guide vane 2, for detecting the suction gas temperature "Ts". In the similar manner, a pressure sensor 13 is also attached or provided within a flow pass for detecting the suction pressure "Ps". A signal of the suction gas temperature, which is detected by the temperature sensor 11, is transmitted to a regulator 27 through a signal line 12. A signal of the suction pressure, which is detected by the pressure sensor 13, is also transmitted to the regulator 27, but through a signal line 13.

For detecting a vane opening " β " of the inlet guide vane 2, a vane opening angle detector 15 is provided in the vicinity of the inlet guide vane 2. A signal of the vane opening, which is detected by the vane opening angle detector 15, is transmitted to the regulator 27 through a signal line 16.

The working gas, which is adjusted in the flow rate through the inlet guide vane 2, is compressed in each of the compressor chambers 4, 6 and 8, to be high in temperature thereof. That working gas of high temperature achieves the thermal exchange between a cooling water or a cooling air, within the inter coolers 4 and 6 and the after cooler, which are disposed in the downstream of the compressor chambers 4, 6 and 8, to be cooled down to about 40 °C. Within the downstream of the after cooler 8 is disposed a check valve 9, and a pressurized gas passing through that check valve 9 is sent to a customer or a consumer. In the downstream of the check valve 9 is attached a pressure sensor 19 for detecting the discharge pressure "Pd". A signal of the discharged pressure,

which is detected through that pressure sensor, is transmitted to the regulator 27 through a signal line 20.

Between the after cooler 8 and the check valve 19 is formed a branch pipe portion 30, within which a blow-off valve 10 is attached.

5 This flow-off valve 10 is provided for preventing the discharge pressure "Pd" from becoming or increasing too much. An instruction signal from the regulator 27 is inputted into a blow-off valve driver 21 through a signal line 22, the blow-off valve 10 is opened, thereby preventing the discharge pressure from increasing therein.

10 The blow-off valve 10 is adjustable in the opening angle thereof. Then, a blow-off valve opening angle detector 25 is attached on the blow-off valve 10, or on the blow-off valve driver 21, for detecting the opening of the blow-off valve 10. The opening angle of the blow-off valve 10, which is detected through the blow-off

15 valve opening angle detector 25, is transmitted to the regulator 27 through a signal line 26. Between the branch pipe portion 30 and the after cooler 8 is attached a surging detector 23, and a signal detected by that surging detector 23 is transmitted to the controller 27 through a signal line 24. Further to the regulator

20 27 is transmitted a target pressure through a signal line 28 from a higher controller means 40.

Detailed explanation will be given about the operation of the regulator 27, into which the various signals are inputted, by referring to the flowchart shown in Figs. 5 and 6. Into the

25 regulator 27 is inputted the target pressure "Pt" from the higher controller means 40. When the regulator 27 starts the control thereof (step 50), it checks on whether the surging is generated or not within the turbo-compressor, with using the surging detector 23 (step 52). The surging detector 23 is attached within the upstream

30 side than the check valve 9, and it transmits the signal 24, i.e., the discharge "Pda" of the compressor, to the regulator 27. When the time change rate, $\Delta Pda/\Delta t$ of the "Pda", exceeds a predetermined value thereof, an abrupt pressure change is produced therein, and

therefore, it is assumed that the surging is generated.

When it is determined that no such the surging is generated within the compressor in the step 52, calculation is made upon the minimum vane opening " β_{\min} " to be set to the inlet guide vane 2 with using the temperature " T_s " and the pressure " P_s " of the suction gas which are detected through the temperature sensor 11 and the pressure sensor 13 (step 54), thereby making a renewal upon the setup of the minimum opening " β_{\min} " of the inlet guide vane 2. Next, upon the basis of the signal, which is detected by the opening angle detector 25 for the blow-off valve 10, it is determined on whether the blow-off valve opening angle " α " is in either a full-closed condition " α_{\min} " or an opened condition (step 56).

When the blow-off valve 10 is in the full-closed condition " α_{\min} ", since the compressor is under the loading operation, then the discharge pressure " P_d " is compared to the target pressure " P_t " (step 58). If the discharge pressure " P_d " is higher than the target pressure " P_t " ($P_d > P_t$), a consumption gas volume is smaller than that of a compressed gas, which is generated within the compressor; therefore, the flow rate is reduced. The vane opening " β " of the inlet guide vane 2, which is detected through the vane opening angle detector when detecting the blow-off opening angle " α ", is compared to the minimum guide vane opening " β_{\min} ", which is set up in advance (step 60). When the setup minimum opening " β_{\min} " is equal or greater than the vane opening, which is detected by the vane opening angle detector 15, i.e., $\beta \leq \beta_{\min}$, the vane opening " β " is widen up to the minimum opening " β_{\min} " (steps 70 and 72). Under such the condition, it is impossible to conduct the flowrate control with using the inlet guide vane, and therefore, the operation is shifted into the so-called an blow-off operation.

When it is determined that the vane opening " β " detected

by the vane opening angle detector 15 is larger than the setup minimum vane opening " β_{\min} " ($\beta > \beta_{\min}$) in the determination of the inlet guide vane opening in the step 60, and also when the discharge pressure " P_d " is lower than the target pressure ($P_d < P_t$) in the
5 determination of the discharge pressure in the step 58, the flow rate control is done so that an appropriate load operation can be obtained. Then, from the difference between the target pressure " P_t " and the discharge pressure " P_d ", deviation of the flow rate is converted into a deviation value " $\Delta\beta$ " of the vane opening, so
10 as to calculate out a vane opening " $\beta_n (= \beta + \Delta\beta)$ " (step 62) to be set up in a next time. The vane opening " β_n " calculated is compared to the maximum vane opening " β_{\max} " (step 64).

When the vane opening " β_n " to be set up is smaller than that maximum vane opening " β_{\max} ", i.e., $\beta_n < \beta_{\max}$, then the setup vane
15 opening " β_n " is compared to the minimum vane opening " β_{\min} " (step 66). If the setup vane opening " β_n " is larger than the minimum vane opening, an instruction is transmitted to the vane driver 17, of moving the inlet guide vane only by the deviation opening $\Delta\beta$, so that it comes up to be the setup vane opening " β_n " (step
20 68).

When it is determined that the setup vane opening " β_n " is equal or greater than the maximum vane opening " β_{\max} " in the step 64 ($\beta_n \geq \beta_{\max}$), however because the vane cannot open wider than the maximum vane opening, then the setup vane opening " β_n " is set
25 at the maximum vane opening " β_{\max} " ($\beta_n = \beta_{\max}$), again (step 74). In the similar manner, when it is determined that the setup vane opening " β_n " is equal or smaller than the minimum vane opening " β_{\min} " in the step 66, the setup vane opening " β_n " is set at the minimum vane opening " β_{\min} " ($\beta_n = \beta_{\min}$), again (step 76). In the
30 manner as was mentioned above, the setup vane opening " β_n " is

determined, so as to drive the inlet guide vane 2 up to the setup vane opening " β_n " with using the vane driver 17 (step 68). Thereafter, the process turns back to the step 52, for preparation of the next measurement thereof.

5 When it is determined that the blow-off valve 10 is not in the full-closed condition in the step 56, since it already entered into the condition of blow-off operation (step 86), the volume of blow-off is controlled or adjusted, thereby obtaining the flow-rate control or regulation. The controlling steps in that
10 blow-off operation are shown in Fig. 6. From the discharge pressure " P_d " and the target pressure " P_t " are calculated out a deviation opening " $\Delta\alpha$ " of the blow-off valve and a next setup blow-off valve opening " α_n " (step 100). The calculated setup blow-off valve opening " α_n " is compared to the maximum blow-off valve opening
15 " α_{max} " (step 102). When the setup blow-off valve opening " α_n " is smaller than the maximum blow-off valve opening " α_{max} " ($\alpha_n < \alpha_{max}$), then the setup blow-off valve opening " α_n " is compared to the full-closed angle " α_{min} ", i.e., the minimum blow-off valve opening (step 104). If the setup blow-off valve opening " α_n " is equal or
20 smaller than the full-closed angle " α_{min} " ($\alpha_n \leq \alpha_{min}$), since this means that the blow-off operation was already completed, then the setup blow-off valve opening " α_n " is set at the full-closed angle " α_{min} ", again (step 106).

 Upon determining the setup blow-off valve opening " α_n ", the
25 flow-off valve driving instruction signal 26 is transmitted to the blow-off valve driver 21, so that the blow-off valve 10 is driven up to the setup blow-off valve opening " α_n " (step 108). The process turns back to the step 52 for preparation of the next measurement. Herein, if the setup blow-off valve opening " α_n " comes
30 up to be equal or greater than the maximum blow-off valve opening " α_{max} " ($\alpha_n \geq \alpha_{max}$) in the step 102, for avoiding the surging therefrom,

the setup blow-off valve opening " α_n " is set at the maximum blow-off valve opening " α_{\max} ". At the same time, the inlet guide vane is turned into the full-closed condition (step 110), to be shifted into a non-load operation (step 112). During the non-load operation, the discharge pressure " P_d " is always measured (step 114). Upon making confirmation that the discharge pressure " P_d " comes to be smaller than the target pressure " P_t " by a predetermined value " ΔP ", the inlet guide vane opening " β " is widened up to the minimum vane opening " β_{\min} " (step 114). Thereafter, the process turns back to the step 100, to start the blow-off operation, again. If the discharge pressure " P_d " comes down to a value obtained from subtraction of the target pressure " P_t " by the predetermined value " ΔP " ($P_d \geq P_t - \Delta P$), even when elapsing a predetermined time period, then the compressor is stopped (step 118).

By the way, when the surging generation is detected in the step 52, then the inlet guide vane is opened for escaping from that surging. An amount of change upon opening of the inlet guide vane 2 at that time is calculated out in a step 78. In this step 78, a minimum compensation value " $\Delta\beta_{\min}$ " of the vane opening is calculated out from an equation or a table, which is preset corresponding to the temperature and the pressure of suction gas. Further, this amount of change may be set at a predetermined value (a constant value), such as, "1 degree", for example. Since the compensation value " $\Delta\beta_{\min}$ " of the vane opening is obtained, then the minimum vane opening " $\beta_{\min} = (\beta + \Delta\beta_{\min})$ " is renewed in a step 80. For avoiding the surging, the inlet guide vane 2 is opened up to the renewed minimum vane opening " β_{\min} ", and also the compressor increases the suction flow rate for it; therefore, the blow-off operation is conducted for the flow rate increased (step 82). This rate can be achieved through widening the opening of the blow-off valve by the predetermined value. Because of urgency when the surging is detected, those steps 52, 78-82 must be executed, almost simultaneously. And, in parallel with the step 82, or after

completion of the step 82, the renewal is conducted upon the database in relation to the minimum vane opening " β_{\min} " (step 84).

In a case when the blow-off valve opening " α_n " is at the maximum blow-off valve opening " α_{\max} " in the step 86, since an amount
5 of load is small, the condition is kept as it is for a predetermine time period, and during this time period is continued the comparison between the discharge pressure " P_d " and the target pressure " P_t " (step 100). In case of determining that the discharge pressure " P_d " is equal or greater than the target pressure " P_t " even after
10 elapsing of the predetermined time period, then the compressor is stopped (step 102). Also, in case of determining that the discharge pressure " P_d " is smaller than the target pressure " P_t ", the process moves to a step 88.

Next, explanation will be made about the setup of the minimum
15 vane opening " β_{\min} ".

Selection is made upon a value having a possibility of being setup as the target pressure " P_t ". If such the values are in plural pieces, such as, " k " pieces, for example, then they are determined to be $P_t(1)$ to $P_t(k)$, sequentially, from the lowest one. The minimum
20 value " $T_s(\min)$ " and the maximum value " $T_s(\max)$ " are determined within a range where they can be expected to have under the circumstances of using the compressor therein. The range of temperature of suction gas between the minimum value " $T_s(\min)$ " and the maximum value " $T_s(\max)$ " is divided into " m " pieces of
25 discrete numbers " $T_s(1)$ ", " $T_s(2)$ " ... " $T_s(m)$ ". For each of the " k " pieces of the preset target pressures " $P_t(i)(i=1, 2 \dots k)$ ", a relationships between the temperatures " $T_s(j)(j=1, 2 \dots k)$ " of suction gas and the minimum vane opening " $\beta_{\min}(i, j)$ " is stored into the database, which is provided within the higher controller means
30 40 or the regulator 27. Further, as the data to be memorized into this database, a standard suction pressure " P_{s0} " is applied to be the suction pressure. Accordingly, the data to be memorized

therein come into an array of data having "kxm" pieces of data thereof.

The minimum vane opening " β_{min} " can be calculated out, as below:

5
$$Pt1 = Pt \frac{(Pt + Pa)/(Ps0 + Pa)}{(Pt + Pa1)/(Ps + Pa1)}$$

When receiving the values of the temperature "Ts" and the pressure "Ps" of suction gas in the form of the signals thereof, then compensation is made upon the target pressure "Pt" with using the suction pressure "Ps", in accordance with the equation
10 mentioned above. Thus, the target pressure "Pt" is compensated with using a property, i.e., that the characteristic curves between the flow rate and the discharge pressure (i.e., the "Qs-Pd" characteristic) come to be similar to each other, if they are coincident with.

15 Herein, "Pt1" is the target pressure after compensation, and it is used only for the purpose of calculating out the minimum vane opening " β_{min} ". Also, "Pa" is the atmospheric pressure under a standard condition, while "Pa1" the atmospheric pressure when detection is made upon the suction condition. Since the target
20 pressure "Pt1" after compensation can be obtained, the minimum vane opening " β_{min} " can be calculated out through the interpolation with using the database mentioned above. However, if the target pressure "Pt1" after compensation comes into an outside of the region of the preset target pressure from Pt(1) to Pt(k), then
25 the minimum vane opening " β_{min} " is calculated out through the extrapolation, in the place thereof.

Explanation will be made about a method of changing the minimum vane opening at the time when the surging generates. A compensation value "Pt1" of the target pressure is obtained from

the suction pressure "Ps" and the target pressure "Pt" when the surging generates. If assuming that the minimum vane opening is " β_{\min} " at the time when the suction gas temperature is "Ts" and the compensation target pressure is "Pt1", then the database is
5 changed, following to " $\beta_{\min 1} = \beta_{\min} + \Delta\beta_{\min}$ ". As was mentioned above, " $\Delta\beta_{\min}$ " can be obtained from the measured values, such as, those of the suction gas temperature "Ts" and the suction pressure "Ps", for example, by using an equation or a data table. Or, it may be given to be a predetermined value (for example, a constant value).
10 Since " β_{\min} " can be guided or obtained by using " $\beta_{\min}(i,j)$ " in a periphery thereof through the interpolation, and if the interpolation is liner, then it is possible to achieve a renewal of the minimum vane opening, by changing the minimum vane opening " $\beta_{\min}(i,j)$ " to " $\beta_{\min}(i,j) + \Delta\beta_{\min}$ ". After completion of that
15 compensation, it can be assured that the minimum vane opening " β_{\min} " will never come down to be equal or lower than the vane opening determined by the surging line, even if the suction gas temperature "Ts" and the compensation target pressure "Pt1" come back to the same values at the time when the surging is generated before.

20 As was mentioned in the above, according to the present invention, it is possible to protect the compressor from the surging within a wide range, by only detecting the temperature and the suction pressure of the working gas sucked into the turbo-compressor. And, it is also possible to operate the
25 turbo-compressor with stability thereof. Further, although the setup of the minimum vane opening is conducted upon the basis of change of the suction gas temperature, according to the present embodiment, however it may be also conducted in the same manner, but upon the basis of change of the suction pressure, as was mentioned
30 above.